

How do we define Metamaterials?

Is it a material with negative ϵ and μ ?

Is it a medium with periodic structures?

Is it an EBG structure?

Is it a DNG structure?

Is a non-foster circuit structure?

Is it based on the equivalent circuit of the propagation mode?

Is it a material with negative phase velocity?

Is it a material with near zero velocity?

Definition from Oct 2011 IEEE Proceedings issue (Eleftheriades)

Metamaterials

Artificially Engineered Materials with Electromagnetic Properties [is the subject of] topics on prescribing material parameters to obtain exotic new functions, physically implementing metamaterials, and applying them in the microwave and optical domains.

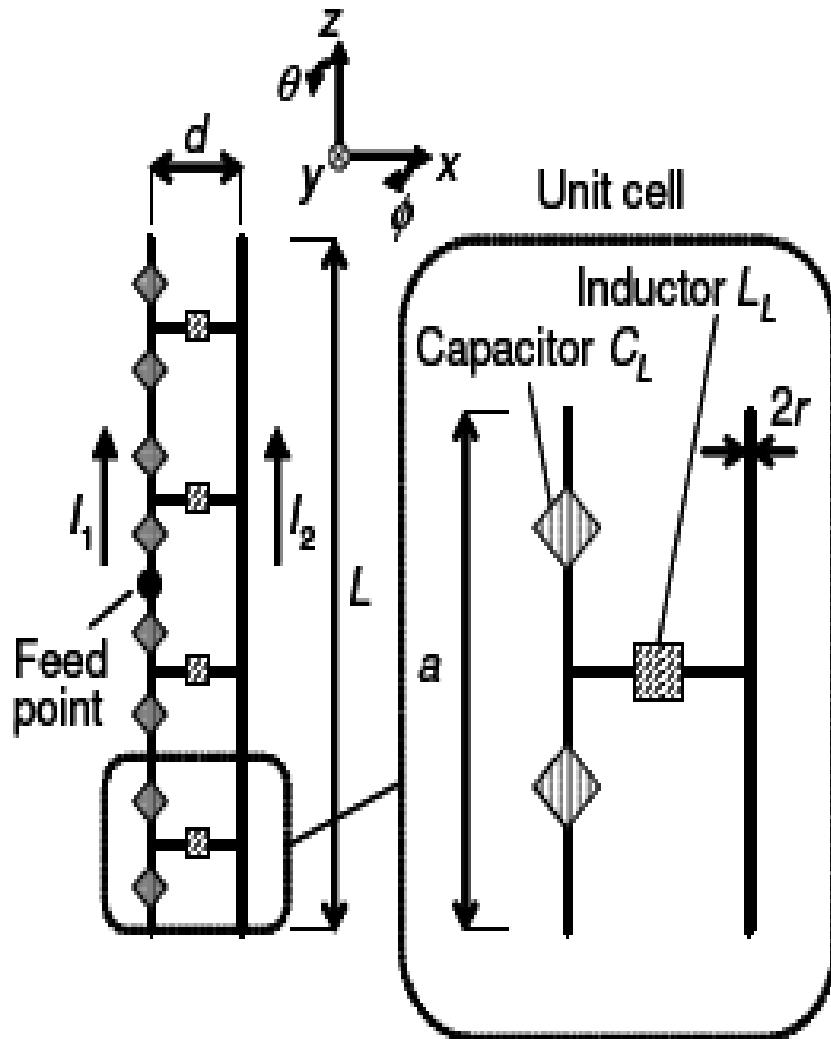
Interpretation: any structure that is man-made (artificial) and leads to new phenomena can be called metamaterials.

This covers a very large set of materials.

Example-1

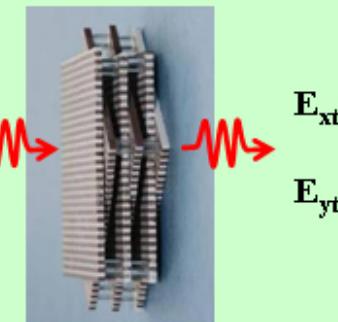
Negative Metamaterial Circuit

From Izuka & Hall, *IEEE Trans Ant and Prop. May 2007*



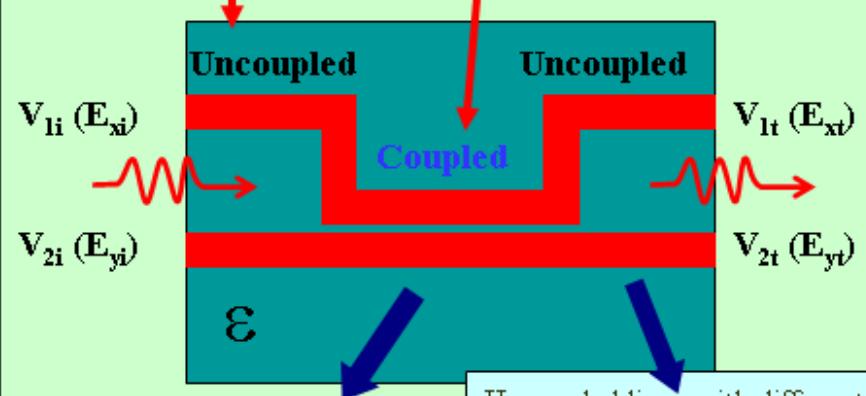
Sertel/Volakis, 2005/2006

DBE Structure – 1D volumetric crystals

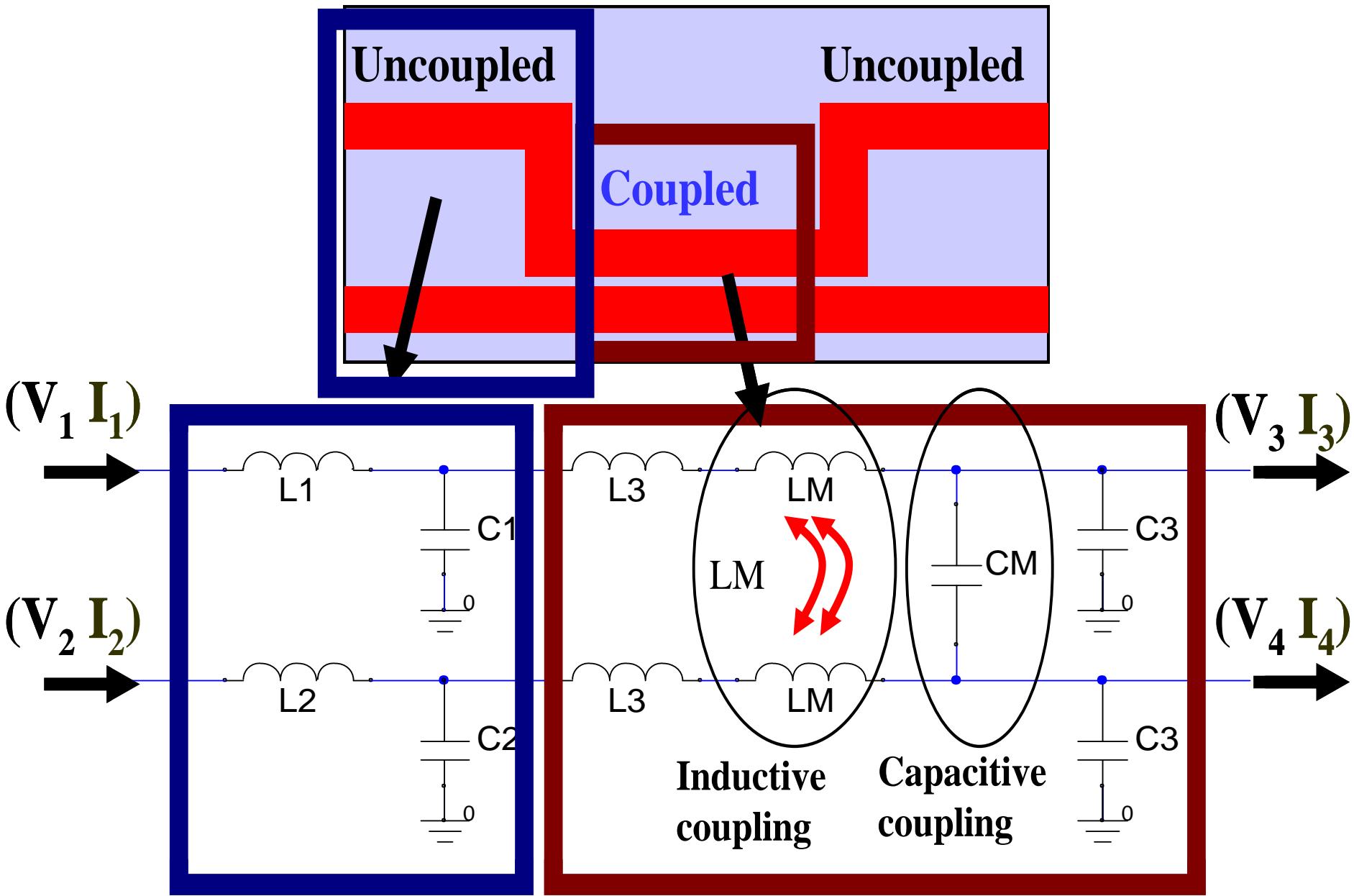


Emulating Anisotropy with Coupled Lines

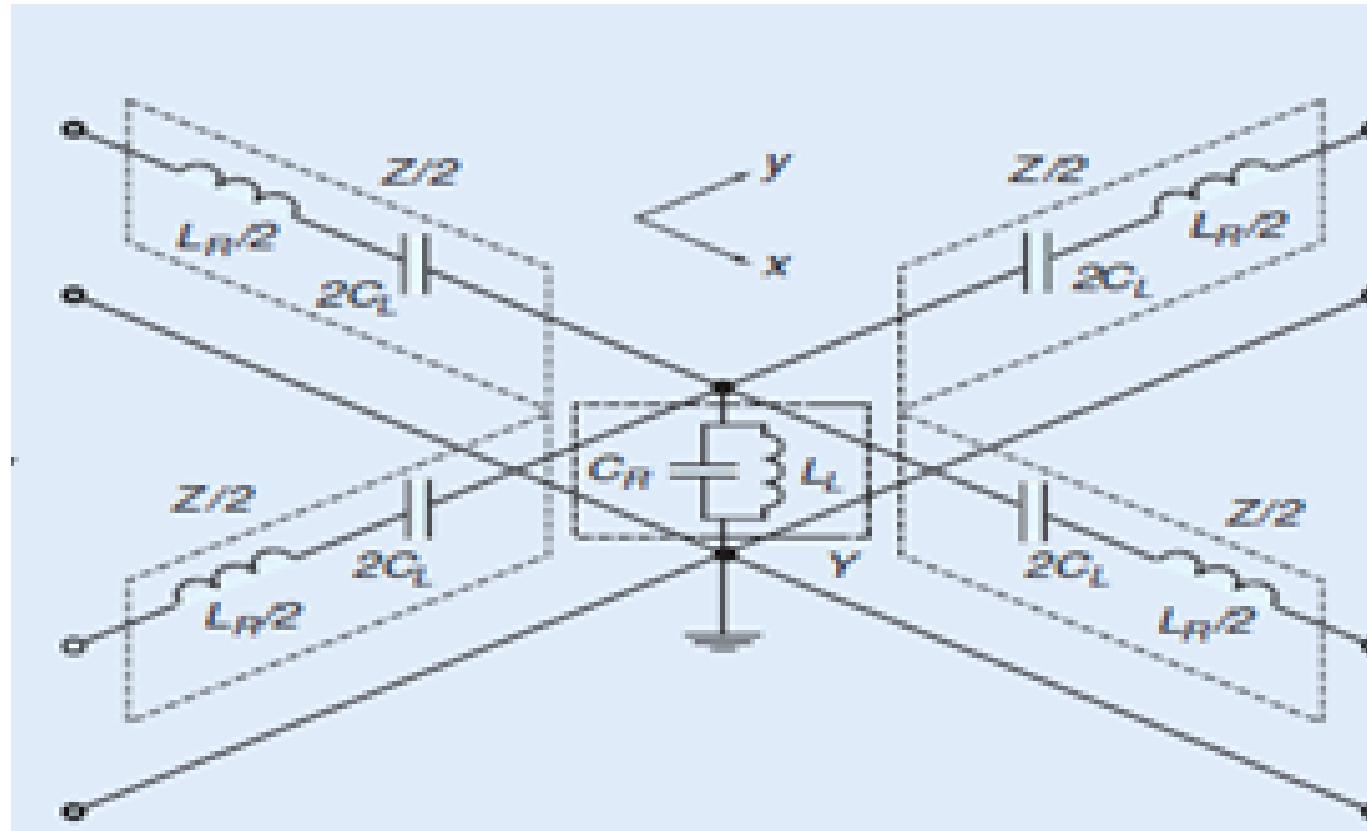
$$\bar{\epsilon}_{\text{eq}}(0) = \begin{bmatrix} 45 & 0 & 0 \\ 0 & 17.78 & 0 \\ 0 & 0 & 45 \end{bmatrix} \quad \bar{\epsilon}_{\text{eq}}(\phi) = \begin{bmatrix} 38.1944 & 11.7876 & 0 \\ 11.7876 & 24.5833 & 0 \\ 0 & 0 & 45 \end{bmatrix}$$



Coupled Transmission Lines



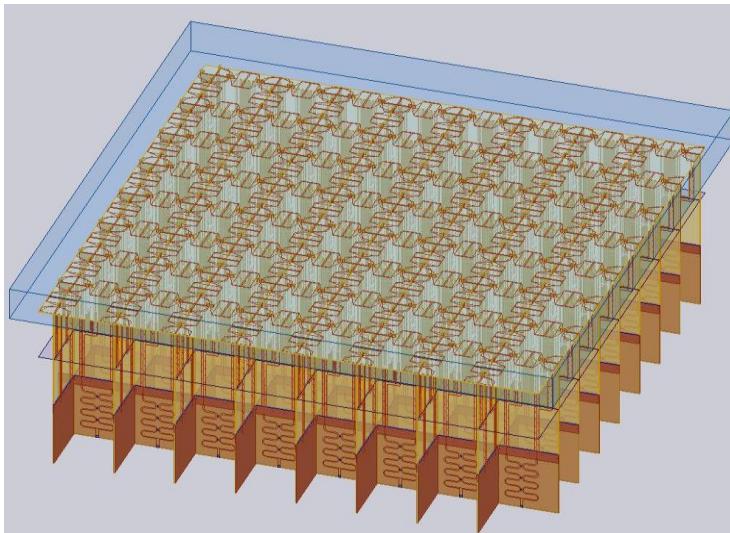
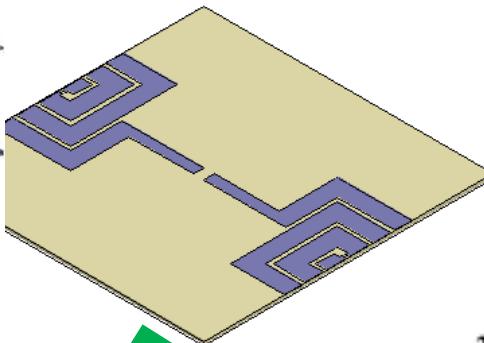
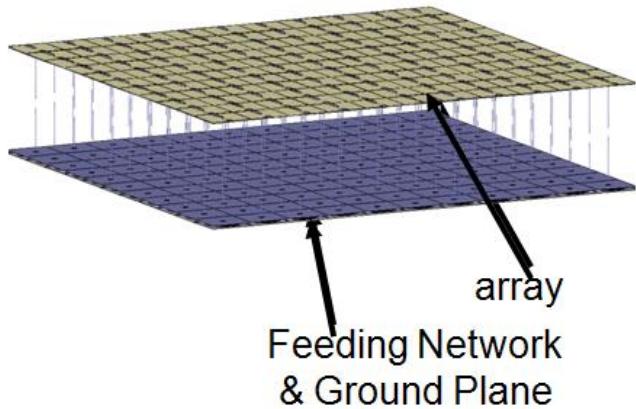
Example 2: General Metamaterial Propagation Circuit



Metamaterial Circuit (from book by Coloz & Itoh, Wiley 2006)

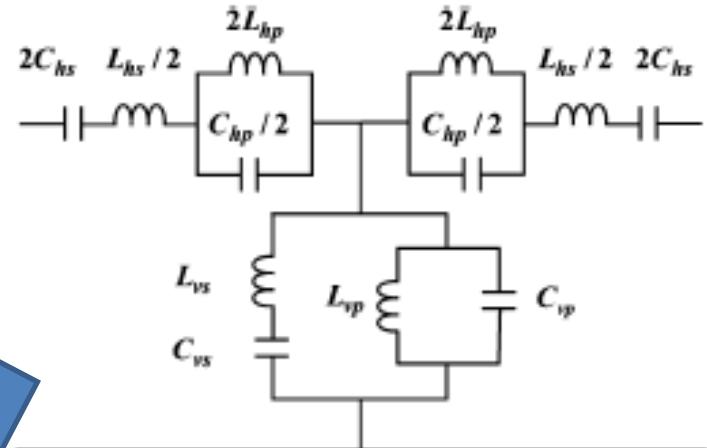
Conformal Periodic Arrays

Doane, Sertel & Volakis, *IEEE Trans. Antenna Propagat.*, Sept. 2013
Moulder, Sertel, & Volakis, "IEEE Trans. Antennas and Propagat.", Nov. 2013.

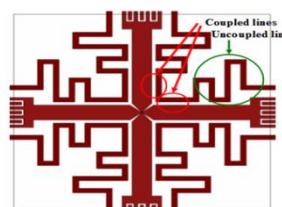
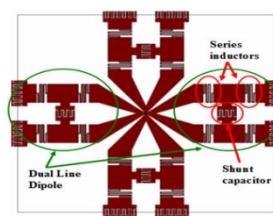


Novak, Papantonis & Volakis
Overlapping Dipole Array with 14:1 BW

Equivalent Circuit



Same at that by Eleftheriades. et.al.



If we realize these composites, we will not need the word *Metamaterial* to impress. Instead, the exotic phenomena themselves will be impressive and exotic

